PIPE LINING'S HIDDEN SECRETS:
Why The Industry Doesn’t Want You To See Inside Your Lined Pipes

Eric Lecky
John Griffith
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Preface

SageWater is the nation’s leading pipe replacement company. With more than 28 years in the business, we have repiped over 85,000 occupied units and replaced more than 32 million feet of pipe along the way. As the largest and only nationwide company focusing exclusively on pipe replacement, we constantly try to innovate and stay ahead of the competition. With many loyal customers who have hired us time and again to repipe various properties in their portfolio, we are always looking for ways to improve and to better serve our clients. Like many companies, part of our innovation strategy involves regularly evaluating new technology, and over the years, we have looked at pipe lining as a potential tool to add to our portfolio of services.

As we went through that pipe lining evaluation process, we encountered a number of concerns that we simply couldn’t ignore, which ultimately led to our decision not to include pipe lining as a component of our core business.

It is our opinion, based on first-hand experience, extensive research, hundreds of hours of due diligence and numerous negotiations with different lining providers and installers, that the risks associated with lining pipes within the building envelope are simply too great for us to consider offering pipe lining to our clients. From health concerns, to quality control issues and invasiveness, to reliability, we cannot in good conscience recommend this solution to our customers for most piping problems.

Despite our conclusions, we continue to encounter properties struggling to evaluate pipe lining as an alternative to repiping due to the scarcity of helpful information. The limited amount of publicly available information about the potential risks of lining solutions has led some owners and property managers to make purchase decisions based primarily on marketing materials provided by the lining vendors.

As a result, we felt compelled to write this paper. In sharing our thoughts and opinions, we hope to shed some light on the limitations and challenges of pipe lining that we have discovered, and to provide insightful considerations that we believe property owners should take into account before deciding to line or repipe their community.

We would like to thank all of those who contributed or have published information we referenced in this paper, including numerous engineers, construction managers, property managers, property owners, lawyers, trade associations, governmental institutions, third party evaluators, and publishers of industry standards as well as the pipe lining manufacturers and installers themselves. In the end, we hope that properties struggling to solve their own pipe problems find this paper helpful as they endeavor to evaluate the pros and cons of various pipe lining and repiping options for their communities.

Sincerely,

Eric Lecky
SageWater

John Griffith
SageWater
Executive Summary

Pipe lining is often viewed as an alternative to “repiping” (installation of new piping to replace old or defective piping) for multifamily apartment and condominium communities. The lining process involves coating the pipes from the inside (or for drain lines installing a “pipe within a pipe”), supposedly creating a long-lasting and maintenance-free solution that solves pipe leaks. Despite manufacturers’ and installers’ claims, however, the challenges with pipe lining solutions are both real and numerous, and the results of pipe lining may be less than desirable.

Piping Systems in MultiFamily Properties

There are multiple piping systems in a residential multifamily property, including supply pipes that bring drinking water into the building, and, drain, waste and vent pipes that carry waste water out of the building; depending on the heating and cooling system configuration, some buildings have hydronic HVAC pipes that connect boilers and chillers to radiators or fan coil units to heat and cool a property. Many people assume that these systems should last a lifetime, and because they are hidden behind walls and underground, they are frequently forgotten until there is a problem (or a series of ever-increasing problems). However, as buildings age, SageWater has found that these systems are in need of repair or replacement, and apartment community owners, property managers and condominium boards are looking for solutions.

Through extensive marketing efforts, the pipe lining industry has positioned itself as a viable alternative to repiping. However, mounting evidence is now calling into question the value proposition and long-term viability of these solutions, and stakeholders should be aware of the limitations and risks associated with pipe lining options.

Pipe Lining Technologies: Epoxy and Cured-In-Place Pipe

To explore the facts about pipe lining, this paper organizes the discussion into two sections that correspond to the two primary technologies currently available in the marketplace for typical multifamily properties: epoxy lining and cured-in-place pipe (CIPP). Within each section, the authors provide an overview of the technology, discussion of installation techniques and key considerations and limitations that should be considered.

Summary Conclusions

Based on extensive research, first-hand observations, detailed interviews and countless hours of due diligence, and regardless of the piping system or the pipe lining technology being deployed, the authors have concluded that lining pipes is not a recommended alternative to repiping for most applications inside the building envelope. By providing an overview of the numerous failures and documented risks of pipe lining, such as health risks, installation challenges, known limitations, reliability, maintenance and cost and warranty concerns, the authors hope to encourage thoughtful consideration before investing in a pipe lining solution and enable building owners, community managers and condominium board members to make informed investment decisions about solutions for their leaking piping systems.
Epoxy Lining

Overview
Epoxy Lining is a general term for a variety of different plastic resins used on hot and cold water supply pipes, sprinkler lines, HVAC piping, gas lines and certain drain, waste and vent piping. The National Sanitation Foundation (NSF) and U.S. Environmental Protection Agency (EPA) have certified some epoxy linings for carrying potable drinking water. Epoxy resins are generally not certified as a “structural improvement” to the existing piping system.

Installation Techniques

Blown-In
This is a common technique for epoxy lining of small diameter [water supply] pipes commonly found in multifamily properties. With this procedure, the pipes are drained and dried by blowing hot air through the piping system. The interior of the pipes are then “cleaned” typically using a “sand-blasting” abrasion process to attempt to remove corrosion from the inside of the pipe wall and hopefully create a clean, smooth surface which is required for proper adhesion of the epoxy resin. The liquid epoxy is often blended onsite and blown through the pipe until, in theory, the walls of the pipe are properly coated. This is done in sections of the piping system, with a “shot” of epoxy theoretically calibrated to be enough to coat the estimated length of pipe being coated, which is forced through by air. It is assumed that when the resin comes out the other end after a shot, that the pipe has been adequately coated. The epoxy then cures for several hours (or even days) depending on the type of resins used. After curing is complete, the water service can be restored.

Spin Cast
The pipes are dried and cleaned in a similar fashion as the process for a blown-in epoxy application. However, rather than forced air blowing in the epoxy from one end of the pipe to the other, a spray head is attached to an umbilical cord rig that is pulled through the pipe, while spinning, to create a centrifugal casting process. This process is computer controlled, creating a more uniform coating throughout the length of pipe being lined. Various resins can be employed using this approach, and various thicknesses can be achieved, but it is only available for larger diameter pipes.

Health and Safety Concerns

Bisphenol-A (BPA), Benzene and Xlyene
BPA has been found to leach out of epoxy resins into drinking water with higher water temperatures yielding higher levels of BPA. Given the concerns over BPA contamination in recent years (and the corresponding negative health effects), it is recommended to always check with both the installer and the manufacturer to ensure the plastic going inside the domestic water pipes is BPA free. Studies have shown that even at low doses [BPA] has been linked to health and environmental problems. [As] a precautionary approach, therefore, many people have reasonably concluded that materials with the potential to release BPA should not be used in drinking water pipes.

In addition, “encourage [customers] to verify that potential contractors are complying with [the specified] application conditions. If they are not, despite their ANSI/NSF Standard 61 certifications, their field installations MAY NOT match the safety levels shown in their lab testing.”
**Possible Installation Concerns**

**Installation Contractor Quality Control**

Our observations/conclusions and the literature indicate that the most common vulnerabilities of the epoxy lining system are associated with the planning and quality of the preparation as well as training of the applicator personnel performing the installation. Short of 100% video documentation, there is no way to know with complete certainty (i) how well the pipes were cleaned and prepared for the epoxy application, which is directly correlated with whether the epoxy will adhere properly to the inside of the pipe, or (ii) if an adequate coating was blown into the piping system.

"The failure modes and vulnerabilities of epoxy are widely known and highly consistent in their progression. It is also widely recognized that the project planning, surface preparation, and precise measurement and application of the ingredients to the substrate are the most significant variables in determining the probability of a successful epoxy coating assignment." In short, when the pipe is not prepared properly or if the epoxy is not mixed properly, there is a greater chance of failure, and both of these variables fall squarely on the experience and quality of the installer. Epoxy installation is highly dependent on the installer, and the quality of any installation is only as good as the installer on the day the pipe was lined.

Because improper installation has such a high potential for materially negative consequences for the property owner, it is critical to determine whether the installation has met the manufacturer’s standards before the contractor leaves the site. As such, the following six recommendations provided by Dan Robles, PE from Community Engineering Services, PLLC should be considered when evaluating epoxy liner solutions for potable water system renewal:

1. Perform a condition assessment to determine remaining material at pitting and threaded areas. Epoxy does not provide any structural reinforcement of the pipe.
2. Review the quality manuals of the contractor for compliance with the governing documents for epoxy liner application.
3. Enforce, record, and document the testing and inspection at time of application and reconcile with ASTM standards.
4. Perform random destructive testing near completion of the project when the contractor is still on site to repair the test section. Consider re-testing near the end of the warranty period.
5. Identify, in writing, the contingency plan should any test or inspection fail at time of commissioning, or should a failure occur over the life of the warranty period.
6. Assure that contractor warranty matches the epoxy manufacturer’s warranty.

The epoxy material must only be applied by authorized applicators (people – not companies) trained by the epoxy manufacturer. Clients should ask for written documentation from the manufacturer that every person on the job has been suitably trained and is in fact an authorized applicator of their epoxy. Plumbing licensure does not suffice in this regard. If the epoxy is applied by non-authorized applicators, the quality of the application becomes an immediate concern.
because a poor application could result in varying degrees of failure. Further, we are not aware of any epoxy manufacturers that will honor a warranty of applications applied by non-authorized applicators.

**Pipe Sanding/Cleaning**

There are two primary concerns with this critical stage of the lining process: surface preparation and potential “blow-outs” during the cleaning process. Before the cleaning process even begins, “existing piping or rigid tubes must be in good condition, with any cracks or leaks or visible signs of corrosion repaired.”

Surface Preparation: If the sanding/cleaning and pipe prep process is not sufficiently completed to the National Association of Corrosion Engineers specifications, the lining may be susceptible to failure. Obtaining that standard of preparation is extremely difficult in complex domestic piping systems. “The abraded pipe, when viewed without magnification, should be free of all visible oil, grease, dirt, mill scale, and loose rust, prepared to a minimum NACE #3 Standard.” If the pipe is not sufficiently prepared, there is no way to know if they meet the NACE standard without a video inspection, corrosion can return and grow under the epoxy (between the lining and the pipe wall) pushing the epoxy back into the pipe. This decreases the diameter of the pipe and may ultimately lead to restricted flow and potential perforation or delamination of the lining.

Blowouts: Structurally decayed sections of pipe can rupture during the sanding process. Supply pipes must be dried and cleaned before they can be lined with epoxy, and this process creates significant stress on the system, sometimes resulting in further erosion of the pipe wall. The stress of the cleaning process will sometimes cause catastrophic pipe ruptures behind walls at weak points in the piping system. This is of particular concern at spots with existing pinhole leaks, anywhere the pipe wall is compromised, as well as at threaded joints, which are typically weak links in a piping system where corrosion is present. At best, these “blow-outs” require cutting holes in the wall or ceiling and replacing sections of pipe before they can be lined. In worst-case scenarios, properties must abandon the lining solution in favor of a repipe because the pipes are essentially “too far gone” to be lined.

**Hazardous Materials Considerations**

The EPA requires all properties built before 1978 to perform extensive testing for the presence of lead and Asbestos Containing Materials (ACMs) prior to disturbing any existing materials, which includes cutting into any wall surface. Due to the permitting process required for a repipe, when a building is of age, HAZMAT testing is always completed before the job begins. Depending on the building configuration, the scope of work for a lining project may not include drywall demolition, and as such, testing may not be completed before the job begins. However, if testing is not done prior to the start of an epoxy lining project and a blowout occurs, the project must stop until such testing can be performed. In such cases, the water supply may be interrupted for as many days as it takes for this process to occur. If, during the testing process, ACMs or lead are determined to be present over the limits set by the EPA, wall demolition must be performed by a licensed hazardous materials remediation contractor under EPA and Occupational Safety and Health Administration (OSHA) approved containment procedures. If this is not planned for in advance, significant work stoppages, increased costs and considerable disruption to residents may occur. Failure to perform the required testing leaves the building owner or Home Owners Association (HOA) board of directors and lining contractor open to significant liability and fines.
Contingency Planning and Protocols
Some pipe lining projects end up requiring sections of pipe to be replaced. In fact, ASTM standards require any damaged or leaking sections of pipe (including those with pinhole leaks) to be replaced before the epoxy lining process can begin. In these instances, the epoxy installer must perform a partial pipe replacement, which raises a series of considerations and questions:

- Does the epoxy installer have documented protocols for opening walls, replacing pipes and communicating with residents?
- Does the epoxy installer have the required licensure to obtain the necessary plumbing and building permits to replace sections of pipe?
- Is the epoxy installer experienced in “fire rated” wall repair?
- Has the epoxy installer obtained the required permits, or will they have to stop work in order to obtain the permits, before the work can continue?
- Does the installer have a contractual obligation to provide protective plastic sheeting and daily clean up to mitigate drywall dust?
- Will the installer guarantee that water supply will be restored every night and on weekends?
- What is the warranty on pipe replacement work?
- Has the building been certified to be free of ACMs and lead? As noted above, walls cannot safely or legally be opened until such certification is obtained. If ACMs or lead are found to be present, the walls must be opened under EPA approved containment procedures performed by a licensed hazardous materials remediation contractor. Epoxy lining contractors may not be aware of this and may not be prepared to coordinate hazardous materials situations.

If a property installing pipe lining ends up with significant sections of piping that requires replacement as a result of the epoxy installation process, an epoxy project could easily end up being more invasive, take longer to complete, and be more expensive than a standard repipe.

Cure Time
Commonly advertised cure times can range from two to 48 hours. Be sure to ask the installer about the required cure time to get a safe and successful result. “If the mixing and preparation of the [epoxy] coating prior to spraying is not performed correctly within fairly narrow and sometimes unforgiving boundaries, the applied lining can be physically and/or chemically compromised.” It’s important to note that historically, epoxy pipe lining started in the naval shipping industry, and was used to line piping in ships that were in dry
dock. Original resins had cure times of up to a week, or longer. Even though the resin formulas have been adapted over the years, some resins may have cure times that require the water to be shut off overnight, impacting residents and the ability of the property to remain occupied. In addition, when it is known that the cure times are lengthy, some installers will develop complex temporary bypass systems in an effort to provide water during nights and weekends. However, these systems (which may involve hoses running throughout the property and through units) can be a major potential inconvenience, or worse, a potential trip-and-fall hazard, for residents and maintenance staff.

In some circumstances, the epoxy may not cure properly, and in fact may fail, if exposed to water before it is fully cured. Environmental conditions can vary from building to building, and different installers may require different amounts of time based on the type of epoxy they are using, complexity of the building piping system, their experience, interruptions, etc. This can all mean that, depending on unforeseen variables, installers may not be able to guarantee a return of service time, leaving the property without water overnight, or potentially longer, without advance notice to residents.

Pipe Run Complexity
Whether blown-in or spin cast, the biggest challenge with installing epoxy lining solutions is when there is a bend in the pipe. The nature of the cleaning process makes it more difficult to ensure the pipe is properly cleaned and prepared on the downstream side of turns in the pipe. Likewise because the airflow around corners such as tees or elbows varies from the inside to the outside of the turn, achieving an even coating of epoxy can be more difficult in these areas. The more turns in a pipe run, the harder it may be to get a uniform coating of epoxy.

Bends in the “pipe run” can slow and complicate a lining solution by requiring additional access points to facilitate lining the various pipe runs properly. Depending on the complexity of the piping system, the installer could end up cutting nearly as many holes as are required for a repipe.

Performance and Maintenance Considerations

Coating Thickness
Epoxy coatings decrease the inside pipe diameter, and depending on the size of the pipe and installer experience, this reduction can be significant. Obviously, the larger the pipe diameter the less percentage loss in volume, but for smaller pipes, like those frequently found in domestic supply piping systems at multifamily properties, this loss can be significant. Buildings are engineered based on specific pipe diameters to ensure proper performance and compliance with plumbing code requirements, and altering the inside diameter of the pipe could have a negative impact on system performance as well as cause the piping system to fall below the standards established by applicable plumbing code.
Flow Impact
Poorly installed linings can result in bottom pooling, where the epoxy settles and creates a flat surface on the bottom of the pipe impacting how the water flows. This can cause a decrease in water volume and flow rate and an increase in turbulence. This may also result in a piping system that no longer meets the current plumbing code regarding pipe sizing.

Future Repairs
The maintenance required on a lined piping system depends on the quality of the installation. If the lining is too thin, too thick, and uneven or does not coat the entire pipe, then there can be considerable maintenance requirements and potential for failure. Likewise, once lined, these pipes cannot be soldered with a torch, as the plastic resins used in the lining process cannot withstand the heat of a flame and melt, creating blockages that require replacement. Depending on the tenure of a community’s maintenance staff, they may not know the pipes have been lined, and may accidentally authorize an uninformed plumber to utilize a torch without understanding the implications. In a California lawsuit against one epoxy manufacturer, it was alleged that “workers used an open flame torch to open up plumbing lines serving a unit. The fire from the torch caught the building materials (epoxy) on fire, and as a result of the fire, several condominium units in the building were severely damaged.”

The approved solution for performing maintenance on a lined water supply piping system is a mechanically formed joint, but with the amount of pressure sometimes required to achieve an adequate seal, there is a potential risk that the lining can crack, leaving portions of the pipe unprotected and loose epoxy in the system potentially causing clogs, delamination or loss of water pressure. With respect to water supply systems, it has been said that “the serviceability issue is not trivial. Homeowners must be comfortable with the idea that no further modifications, maintenance, or improvements can be made on their current potable water system.”

Known Limitations
Hot Water, Hydronic and Commercial Concerns
The commercial application of epoxy and long-term implications of hot water exposure (such as in boiler fed properties) are also causes for concern. While some epoxy lining contractors have NSF approval for high-temperature hot water interaction, these providers will typically not warrant the epoxy solution beyond 140 degrees. While set points for domestic hot water temperatures are typically in the 120 to 140 degree range, boilers may cause a spike in temperature above this level, potentially compromising the integrity of the epoxy lining. This is particularly true for properties that routinely boost their boiler temperatures to 150 degrees or higher to prevent and/or kill Legionella.
bacteria. As such, proper due diligence should take place before deciding if an epoxy lining is suitable for a building's hot water piping.

In addition, the chemicals added to hydronic piping systems to help maintain the life of the equipment and improve efficiency may or may not be approved to interact with the epoxy resin. Any lining of hydronic systems must be carefully considered and tested before potentially creating an undesirable chemical reaction.

**Lack of Exterior Corrosion Protection**
At best, epoxy lining may help reduce leaks originating at the interior of the pipe. That's only half the problem. Exterior corrosion can also be the cause of pipe failures, and epoxy lining does nothing to address this issue. This is particularly problematic on hydronic cooling systems where insulation failures over time have led to condensation on the outside of the pipe, resulting in exterior corrosion. It can also be a problem for cast iron drain, waste and vent piping systems. In the end, an epoxy liner may only be a Band-Aid® to temporarily address the symptoms (leaking pipes) without curing the root cause of pipe deterioration (electrolysis, condensation, etc.)

**Potentially Limited Interior Corrosion Prevention**
If the installation process isn’t adequate, corrosion can continue between the pipe and the liner, ultimately eating through pipe, the liner, or both. Generally, epoxy is not a structural material, so this presents a potential problem on domestic water supply systems. If lining is too thin, or has holes, or if the pipe was not sufficiently cleaned almost perfectly in the “sand blasting” process, corrosion can potentially eat through the lining causing delamination and leaks that persist. Considering that corrosion is the key driver behind having to perform the renovation in the first place, and lining is often promoted as stopping future corrosion, to what extent is a lining contractor willing to warrant against future corrosion? The biggest consideration with regard to corrosion from the inside of the pipe is uniformity of the applied lining product and most importantly, the thoroughness of the pipe cleaning process. And as explained above, lining will not prevent corrosion on the outside of the pipes from continuing.

**Partial System Coverage**
This should be a major point of consideration for a prospective buyer of a lining solution. Typically, valves cannot be lined, and if they are, the valves will not work. Depending on the system, some simple fittings such as tee's, may not be able to be properly lined because of the challenges with air volume going around the corners (both for cleaning the pipe before lining and for blowing in the resin). As such, some lining solutions only cover the straight sections of pipe, leaving fittings and valves uncovered and at risk of further corrosion if not replaced. Likewise, where the lining stops, there is always the risk of water (and corrosion) getting between the lining and the pipe wall, so the more “gaps” in the piping system, the greater the risk. The best way to get “complete” coverage is to repipe the property, removing all the old components and replacing them with new ones.

**Not Always Approved For Plastic Pipes**
Some epoxy resins have not been approved by the NSF or the International Association of Plumbing and Mechanical Officials (IAPMO) for lining PEX and other plastic supply piping, as the resin requires a rigid
surface to coat and adhere to the pipe. The problem with this is that many properties have repaired pinhole leaks in galvanized steel or copper piping systems with PEX or CPVC where sections of metal pipe have already been removed and replaced with a plastic alternative. If, for example, an epoxy vendor is bidding on a project that has had a large number of PEX repairs, they could unknowingly create conditions that fail to meet manufacturers specifications by using epoxy on the PEX portion of the piping system. This means they would be required to either not coat those parts of the system, or replace the plastic pipe with metal pipe before proceeding with the lining job. The risks are that the epoxy may not adhere properly which could lead to delamination and it may not be a compatible material with the plastic.

Lack of Governmental Inspection
Epoxy lined pipes typically are not inspected by any governmental or third party agency. Unlike a repipe that is inspected pursuant to the local government’s approved code, there is a very limited ability to perform third party inspections for epoxy installations without randomly removing sections of pipe. With no one checking on the quality of the installation, buyers must simply trust that their contractor is installing the solution appropriately. Unfortunately, based on observations of real world failures, this is often not the case. As such it is highly recommended that an epoxy-qualified third party inspector be retained to perform random destructive testing throughout performance of the project to ensure the work meets all required standards.\textsuperscript{15}

The ICC-ES (International Code Council – Evaluation Services) is a nonprofit, limited liability company that does technical evaluations of building products, components, methods, and materials. The evaluation process culminates with the issuance of technical reports that, because they directly address the issue of code compliance, are extremely useful to both regulatory agencies and building-product manufacturers. Agencies use evaluation reports to help determine code compliance and enforce building regulations; manufacturers use reports as evidence that their products (and this is especially important if the products are new and innovative) meet code requirements and warrant regulatory approval.\textsuperscript{16}

Epoxy manufacturers can submit their products to ICC-ES for approval. Upon being certified, those manufacturers can then use the ICC-ES stamp of approval as a credential to promote their material under the claim that it has been evaluated and approved by a third party testing service. However, these approvals come with specific stipulations regarding the use and installation of the product. For example, when addressing epoxy lining of a domestic water piping system, one of the ICC-ES Installation requirements states:

“After drying in accordance with the manufacturer’s instructions, the (insert provider) then reassembles the piping system and hydrostatically pressure tests to 150 psi in the presence of the code official or the official’s designated representative. In the presence of the code official or designated representative, the (insert provider) applicator then conducts a flow test to verify the minimum flow rate to each fixture...”\textsuperscript{17}

Unfortunately, performing a flow test to each and every fixture in a high-rise multifamily community (in the presence of a code official) may simply be too time and labor intensive to be practical and may potentially be skipped in many applications. In this scenario, epoxy installers would be in violation of the very same ICC-ES code that they promote as part of their own credentials, rendering the third party approval invalid.

Challenges with Larger Diameter Pipe
Larger pipes (anything over 2 to 2 ½-inches) require the use of a massive air volume for the blown-in installation process. 3-
inch to 4-inch pipes are exceedingly difficult to properly coat with high pressure air, and many epoxy lining companies will not include those larger pipes in their scope of work. If there are large supply mains on the property, repiping may be the only recommended choice.

**Warranty Issues**

**Manufacturers’ Warranties**

For several manufacturers, the warranty on their product is practically non-existent. If there is a defect, they will ship some epoxy compound to make a repair and no labor is covered, placing all the liability on the installation contractor. Others claim life expectancy of up to 50 years, though the industry is too new to substantiate such claims with actual installations. Lastly, warranties are limited based on water temperature, and voided if hot water systems are above certain levels (140 degrees Fahrenheit for several manufacturers).

Always confirm the warranties of both the manufacturer and the installer before making a purchase decision. In its own product literature, one manufacturer states: “Long-term durability of an applied epoxy lining depends on various factors related to resin formulation and contractor performance including:

- Physical and chemical properties of the epoxy material
- Proper surface preparation and cleanliness of pipe interiors prior to lining
- Quality of site application, including the stability of the mix ratio and curing conditions and,
- Sensitivity of the epoxy material to application conditions

In view of these factors and their various potential combinations, it is apparent that the behavior of lining systems could differ greatly even within an individual rehabilitation, making assessment of an open ended statement of long-term durability difficult.”

**Installers’ Warranties**

It is important to understand how long the installer is offering to warrant workmanship in the event it is determined that they failed to properly install the lining product. In addition, it’s important to understand if the installer will match the manufacturers’ warranty if there is an issue with the product for which the manufacturers’ warranty only covers materials and not labor. Likewise, it’s important to understand if repairs covered under warranty; will be completed by a technician who is certified on the lining product that was installed. Locating a certified technician to perform a repair under warranty on a particular lining product could be a challenge in some local markets as most local service plumbers and maintenance personnel are not trained on working with lined pipes.

**Bondability**

For a number of reasons related to the requirements of the bonding company, pipe lining installers may not be able to obtain or provide payment and performance bonds. The key question to ask in this regard is: “Even though payment and performance bonds may not be a bid requirement, would a community feel comfortable hiring a contractor that does not have the ability to bond (obtain a third-party guarantee) their work?”
Cost Considerations and Invasiveness

There are many things that call into question the efficacy of pipe lining. When taken together, consumers may come to the conclusion that pipe lining is simply not a viable solution to their pipe problems. So why do consumers ever consider lining? In reality, there are really only two claims made by epoxy installers that if true, could be reasons to line pipes rather than replace them. Epoxy lining companies often claim that lining is less expensive and the process is less invasive. In many cases, neither of these claims is actually true.

As mentioned, the greatest determinant of success or failure is the training and experience of the epoxy applicators specific to the characteristics of the system being renewed. Unfortunately, there are very few reliable methods to test an application and limited options for mitigating application failures, with the best option often being to re-pipe. Epoxy is a remarkable substance and it is assumed that epoxy can be applied correctly, but the cost of doing so may match or exceed the cost of a re-pipe in modern materials.

Invasiveness of Lining vs. Pipe Replacement

The claim that pipe lining is less invasive depends on what one considers invasive. Pipe lining usually requires the removal of every valve in the system and disconnecting all supply lines from every fixture (faucets, tubs, hose bibs, commodes, etc.). Once this is done a spider web of hoses is typically run throughout the home, apartment or condo unit to each area where the supply lines have been disconnected. This can be extremely invasive, to the point that the work areas are not useable as a practical matter during the process. During the cleaning phase of lining, high pressure air and abrasives “sand blast” the inside of the pipe in an effort to remove all corrosion, particulate or film so that the metal will accept the epoxy. As mentioned, this process often causes weak areas of the pipe system to rupture behind the walls. At that point the process must stop, the ruptured areas must be found by cutting holes in the wall, a partial pipe replacement must be performed and the walls must be repaired, finished and painted. This can often take longer and be more intrusive than simply replacing the pipe to begin with. In addition, required dry times for epoxy must be adhered to, which may mean that water is not available over night while the epoxy dries.

By contrast, the repipe process is quick and guaranteed to minimally disrupt the resident. Holes are cut surgically in the walls in order to route new piping in the most efficient manner from the piping entry point in the home to each fixture. The old pipes are removed if they are in the way or abandoned in place if not. This process takes just a few hours in total after which the new pipes are installed, the same day in most instances. At the end of day one, the unit has a new piping system. For experienced repipe companies with in-house wall finishers and painters, the wall restoration process is quick and painless. The pieces of drywall cut to access the walls are reused and put back in place, finished and painted to match. This generally takes one or two days and the home is usable throughout the entire process. If an experienced repipe contractor is used, residents do not have to move out during the repipe process. Water is only off for a few hours while the pipes are being installed, and a reputable repipe contractor will guarantee that water is back on and the unit is fully usable each evening.

So which process is likely to be more invasive? Is surgically cutting holes in walls to install a brand new piping system (a process that generally takes one day) more invasive than running hoses all over the building and possibly leaving it without water overnight?
**Cost of Lining vs. Pipe Replacement**
While pipe liners may claim they are more cost effective than repiping, this has not generally been SageWater's experience. There are occasional circumstances when lining is cheaper, such as when the pipes that are leaking are buried underneath a concrete slab and cannot be abandoned and rerouted (a standard practice in the repipe industry). In this case, accessing the pipes to replace them can be costly and temporarily fixing the line with an epoxy solution may be desirable. However, for a more traditional repipe vs. lining scenario, it's always important to get bids on both solutions to truly compare the pros and cons. In head to head competition between the cost of a completely new piping system and an epoxy lining solution, SageWater has often seen that properties can repipe at a lower cost than lining. There are also cases where properties decided to line their pipes, only to find the system was too far deteriorated or the lining was not completed properly, and they ended up having to repipe anyway, considerably increasing their costs.

**Hybrid Solutions**
Pipe lining often leads to a partial (or complete) pipe replacement anyway. Depending on the condition of the pipe being lined, large portions may need to be replaced before the system can be lined. Since installers cannot line valves and sometimes fittings, in many cases only the straight runs are lined. In these cases, valves will need to be replaced whether the system is lined or repiped. Frequently, the costs of a mixed solution (partial lining and partial replacement) can be considerably more expensive than just a straight replacement of the entire system.

**Litigation**
Without a doubt, this is the greatest unknown potential cost of a pipe lining solution. Installers and manufacturers are currently embroiled in numerous lawsuits involving claims of poor product performance and/or improper installation. A recent search for cases pertaining to epoxy lining of pipes found no less than a dozen cases claiming negligence, fraud, breach of contract, breach of warranty and construction defect against the manufacturers and installers.

In the end, Dan Robles, PE from Community Engineering Services, PLLC sums it up best in the following statement excerpted from his “Epoxy Paradox.”

**The Epoxy Paradox:**
...The question arises that if an application should fail a test or inspection, what is the contingency plan to remediate the flaw? How will the epoxy be removed and how will the recoating be applied? If a single failure is found, what test sampling strategy must be applied to give a high likelihood that no other flaws exist in the system? Under what warranty claim would a failed test be covered and to what extent will coverage be warranted?

**The serviceability issue is not trivial.** Homeowners must be comfortable with the idea that no further modifications, maintenance, or improvements can be made on their current potable water system.

**Double Jeopardy:** When an epoxy failure does happen, it is likely to occur at the location where the pipe is already at its weakest; pitted areas and threads. As such, a poorly applied epoxy liner could weaken a pipe considerably. The result could be a catastrophic high-volume pipe failure requiring a high insurance payout, which would not otherwise be attributed to epoxy coating.

**Epoxy Lining Conclusions**
The overwhelming amount of risk associated with epoxy lining, coupled with observations of failed installations and their consequences, has led the authors to conclude that epoxy lining pipes within the building envelope is not a comparable alternative to pipe replacement. Before making an investment decision, it is always advisable for a community to explore all its options, including a repipe, to ensure their property is making the most informed decision possible about fixing its leaking pipes.
Cured-In-Place Pipe (CIPP)

Cured-in-Place Pipe (CIPP) solutions have been around for decades and have been proven to extend the lifecycle of underground sewer lines that are simply cost prohibitive to excavate and replace. As a lining solution, CIPP is appropriate for systems such as underground, larger diameter drain and sewer lines, where access costs are very expensive and there are fewer connections to be concerned about. CIPP linings are thicker, heavier, resin impregnated liners, such as felt or fiberglass, that cure to a hard, structural finish, essentially creating a pipe within a pipe.

Practical Considerations

CIPP was not originally designed as a substitute for the complete repipe of the interior drain, waste and vent (DWV) system within a building. A quick internet search of “CIPP pipe lining” provides a wealth of information about the application of CIPP as an underground pipe repair method. Today, a few companies claim to be able to use a CIPP solution as a substitute for a complete building repipe, but as a practical matter, ASTM guidelines, industry guidelines such as NASSCO (National Association of Sewer Service Companies) and manufacturers specifications for CIPP make such an application impractical at best and potentially impossible.

A few pipe lining companies have attempted to apply this technology within the building envelope, claiming it can be used as an equivalent substitute to a complete repipe. However, it is nearly impossible to install CIPP in every DWV pipe in the building such that it will meet all manufacturers’ and industry standards and therefore be properly considered an equivalent substitute to a complete repipe. NASSCO standards require that CIPP “when cured, shall be continuous and tight-fitting throughout the entire length of the original pipe. The CIPP shall extend the full length of the original pipe and provide a structurally sound, joint-less and water-tight new pipe within a pipe.” The complexity of an interior DWV system, with the myriad of pipe sizes, connections, cross connections to vents, turns, wyes—all behind the walls where they cannot be seen or evaluated—make it incredibly difficult, if even possible at all, to achieve this standard. At best, a CIPP product could create a series of patched pipes, like a series of stints between each fitting, leaving a gap every few feet where lateral pipes tie into the vertical stack. However, this leaves an unsealed opening at each CIPP section’s termination point at the annular space between the new CIPP and the host pipe. Industry standard requires this space to be sealed with a CIPP compatible sealant, but to accomplish this the building walls would have to be opened at each fitting, the fitting extracted, the CIPP sealed to the host pipe and a new fitting installed. Such a project is throwing good money after bad as the cost of a complete repipe of the system may actually be less than the cost to attempt to reline the entire piping DWV system, and the results of a repipe are guaranteed to bring the building’s piping system back to its original, like-new condition.

Installation Techniques

Pull Through (Bladder)
A pulled-in-place installation requires two points of access for each section of pipe to be lined. For cured-in-place applications, the pipe must first be cleaned using high pressure water jetting, “sand blasting,” or
other mechanical means to remove all rust, tuberculation and build-up of waste material from years of use. Then a resin-saturated felt liner containing an internal bladder is pulled through the pipe that is to be lined from one access point to the other, stopping before each intersection with another pipe, tee or fitting or running through the fitting requiring reinstatement once the liner has cured. The bladder is then inflated to push the liner against the pipe wall. The liner cures while the bladder is inflated, and then the bladder is removed, leaving a rigid lining inside the pipe.

**Inversion**

As with the pulled-in-place method, the pipe must also be carefully cleaned and prepared for the liner, and then the liner is “rolled in” through the pipe. Similar to a sock being unrolled, air or water is used to force a saturated liner to invert (or unroll) inside the pipe, each section of pipe is left inflated with air while the liner cures in place.

Regardless of the installation technique, some CIPP resins are able to cure at ambient air temperatures while others require heating the air and resin to specific temperatures for the resin to set properly. “Improper curing (either under or over-curing) of the thermally cured liners is a significant problem in the CIPP process. Curing temperature and time are the two most important parameters that are intimately linked, and if the perfect combination between them is not properly followed during the curing process, the end product may suffer damage or wrinkles or folds may occur in the liner.”

**Key Considerations**

**Pipe Run Complexity**

Whether pulled through or inverted, the biggest challenge with installing a CIPP solution inside the building envelope is when there is a bend, tee, fitting or turn along the run of pipe, of which there are thousands in every building. The more fittings, tees or turns in the pipe, the harder it is to get a good, consistent lining. It is SageWater’s opinion based on many years of experience that it is simply impossible to properly CIPP line the entire above-grade waste and vent system in any building.

CIPP solutions are generally designed to work in straight lines, with special care and techniques used to line through a limited number of turns in an otherwise continuous underground line. With no good solution for joints such as tees, wyes or other pipe fittings, gaps are intentionally left, leaving part of the system exposed at every fitting. Within the building envelope, there are many areas where the pipe design is extremely complex and requires huge numbers of fittings, bends, and tees. These complexities are not typically shown on any plans, so there is no way to know how they are built without opening the walls. Likewise, the felt liners used in the CIPP process are specifically sized according to the size of the pipe. The more transitions in pipe size, the more cuts, joints and transitions in liner size, rendering the lining process much more complex, difficult and expensive.

How can a pipe liner installer ensure that each section of pipe is completely cleaned and prepared to receive the liner? Designed to be installed in a straight pipe, how will they pull the liner around multiple corners, maintaining the original shape and inside-diameter of the host pipe? The reality is that all of those sections
must be replaced, which negates any possible reason for attempting pipe lining in the first place. As such, CIPP solutions are only partial solutions, because installers simply cannot line certain fittings and areas of complex pipe design, even in the best of circumstances.

**Waste vs. Vent Lines**

Many properties think they only need to worry about lining their waste lines, as those are the ones that carry corrosive effluent out of the building. Properties often think they can save money by keeping their existing vent lines. Unfortunately, vent lines are also prone to failure as the corrosive nature of the gasses can cause significant damage to these pipes. Lining vent lines, with their changing pipe sizes and numerous fittings can be very challenging and costly. However, they must be addressed to ensure the system is safe and functioning properly, otherwise waste gasses can leak into the building causing health and odor issues for the residents.

**Testing and Inspection**

The industry testing and inspection requirements require video inspection of the pipe before and after cleaning and prepping the pipe for installation and after the installation of the CIPP liner to assure that there are no wrinkles, gaps, thin spots, etc. in the system. Has a third party, such as a construction manager, been hired to review the work and the videos? According to NASSCO, the pipe liner must be inspected completely, from end to end, after installation to ensure that a proper installation was achieved. It may not be practical to CIPP-line and then video every section of DWV pipe in the building for the complexity reasons cited above. Simply put, without this complete visual inspection, the job will not meet industry standards.

ASTM and industry standards also require that the strength of the pipe liner as well as other properties of the finished liner be tested after the installation by cutting out random sections and performing the required tests. This will require opening walls throughout the building, removing pieces of pipe and liner and performing the necessary testing. Without performing these tests the finished system will not meet industry standards for installation.

**Environmental Considerations**

CIPP lining is different from epoxy in that DWV pipes are open to the environment, such as vent lines that run to open air on the roof. This represents environmental challenges related to both air quality (vent lines releasing gasses into the environment) as well as water quality (drain lines that feed directly into the ecosystem such as rain leaders).

While epoxy is theoretically engineered to be safe because it carries potable drinking water, CIPP resins do not have these same requirements because they carry waste. Always check with your manufacturer or installer about the potential toxicity of the chemical components that are included in their lining products. “Of particular concern are the potential effects of styrene, which is a significant component of the polyester resin and vinyl ester resin that sometimes saturate the lining tube.” The EPA has classified styrene as a mutagen and considered it as potentially carcinogenic.

From a run-off perspective, there have been several documented cases of resins showing up downstream and having a negative environmental impact, either as a result of spillage or trickle down and discharge through the piping system. “The literature reveals that spills of uncured resins in just a small number of CIPP installations resulted in large fish kills. For instance, about 3-4 gallons of uncured resin were released in the course of a CIPP installation on a storm water drain; the residual uncured resins were conveyed to a creek, causing the death of more than 5,500 fish of several species.”
Vent lines connected to DWV systems are exposed to the air and potential environmental concerns regarding off gassing are real. “A few reports reveal that CIPP application may create environmental challenges by emitting styrene and/or other VOC (volatile organic compounds) in the air. For instance, during a CIPP application in Birmingham, UK, nearby residents were complaining about noxious fumes inside their homes. Results from an indoor air test in one house showed styrene levels of 200ppm, and CIPP contractors advised some residents to evacuate their homes (Bourbour Ajdari 2016). Whelton et al. (2016) compiled numerous indoor air contamination anecdotal reports from building residents near the CIPP sites, and the highest indoor air styrene concentration found was 500 ppm. A major finding of this study was that indoor air contamination incidents have occurred, but quantitative air monitoring data are lacking.”

Of greatest concern is the fact that all these reported environment concerns took place in an outdoor environment lining underground sewer lines. Bringing this technology, and these environmental concerns, inside the building envelope could pose considerable health risks to residents and their families.

**Known Limitations of CIPP Solutions**

**Partial Coverage**

By their very nature, CIPP solutions only cover certain parts of the pipe when deployed for interior drain and vent piping. Depending on the system, some simple fittings such as tee’s cannot be lined because it creates edge conditions that are not acceptable. As such, many CIPP solutions only cover the straight sections of pipe, leaving fittings uncovered and susceptible to further corrosion. Likewise, when the lining stops, there is always a lip that serves as a catch point for the waste, creating a greater risk for build-up and corrosion at the point where the lining starts and stops.

When there is a connection within a pipe run, be it a joint such as a tee or connection to a fitting such as a valve, there are two potential solutions:

- **Reinstatement** – In this scenario, the entire run of pipe is lined, and then a tool is used to cut holes in the new lining where there is a connection. Prior to lining the pipe, the locations of these connections must be carefully measured to ensure the holes are cut in the right place. “Service connections are reinstated by cutting a hole in the liner at the spot of each lateral pipe and those cutouts are typically the only breaks in the continuity of the liner ... Sometimes, it is usual for the cutouts to be uneven, overcut, or undercut, and therefore not the same size and shape as the lateral pipe and it is recommended to install short tee connection liners in these locations.”

- **Gapping** – This means they will pull a liner into place and leave a gap at the fittings and start again after the fitting. This cost-cutting compromise is required to avoid complications at pipe intersections and valves. The problem is that gapping creates pits or lips inside the piping that can create clogging or build up points in the piping and there is no protection for the part of the system that is gapped.

**Challenges with Smaller Diameter Pipe**

CIPP installation in small diameter service laterals (4-6 inches) may be challenging. Small diameter pipes have more difficulty accommodating the pull-through or inversion processes, as there is limited room to insert a liner and inflate a balloon. Likewise, the resulting reduction in pipe diameter could be significant.
and may create drainage problems. When installed, drain piping is engineered to meet code requirements. Reducing the usable diameter of the pipe by installing a lining may result in pipe that no longer meets code for its intended application. In this instance, these drain and vent lines should be replaced rather than reducing the inside diameter to a point where the pipe is no longer code compliant. To get around this, some lining installers line only the larger diameter drain and vent pipe but may call their solution a “complete repair.” This may not be the case. If the smaller diameter pipe and the connections between the larger pipe and smaller pipe are left unprotected, the system may still be at substantial risk and exposed to potentially unwarranted failures. The only way a property can secure complete confidence that it is receiving a fully warranted “complete repair” is with a total pipe replacement of the entire DWV system. Unfortunately, buildings can be misled by the lining companies that they are getting a quality repair when in reality, they are only getting a partial, temporary solution.

Disruption
As with epoxy lining, multiple access points are required for a successful CIPP lining installation. This requires cutting many holes in the walls to access the piping, as well as significant and sometimes lengthy building shut downs while the lining work is taking place and the CIPP liners are curing. Before considering a CIPP solution within the building envelope, it’s critical to understand the impact of the installation compared to the impact of a repipe. It is possible that a repipe may be both quicker and less invasive than a CIPP solution.

Pipe Grade Concerns
One common problem with aging lateral waste line piping is that the structural integrity of the pipe decreases and often times results in a malformation of the pipe grade, creating sections of pipe with sags or bends. It’s important to understand that no lining method will rectify pre-existing grade deficiencies.

Quality Control Issues
As with epoxy linings, the process followed during installation must be almost perfect to have a reasonable chance of a lasting repair. “Relining using CIPP is not a straightforward process and has a number of issues and challenges. Risks and/or deficiencies in a CIPP project may result in a direct economic loss to the industry. For instance, deficiencies such as uncured linings must be fixed using spot repair or a full removal and replacement of the liner, causing a significant cost impact.” As an example, the pipe must be cleaned to almost like-new condition before the liner is installed. If this process is not done correctly, if the installer takes a short-cut in any way, or it is simply impossible to determine visually that the pipe has been properly cleaned, the system may be susceptible to delamination and continued corrosion. When conscientious installers aggressively clean the pipe surface, they can also shatter the fragile pipe, requiring sections to be replaced anyway.
Broken System Components
Frequently during a repipe when the walls are opened up to replace the pipe, failing no-hub coupling straps on drain and vent lines are discovered. In these scenarios, the pipe run itself is compromised, and there is a significant risk of failure if lining is attempted without replacing the straps. Likewise, whole sections of pipe are sometimes missing in corroded vent lines. The property is often aware of these structural gaps and failures due to odors in the building, but finding and repairing these areas prior to lining can be a challenge. Worse, if they are not found, then the lining process can become a mess behind a closed wall, resulting in significant delays and cost increases to make repairs.

Lack of Exterior Corrosion Protection
The existence of exterior corrosion can be a major problem. And in many cases, cast iron piping within a building is so structurally compromised that there is no way to install a liner at all. It is important to understand that at any unlined section, such as at fittings, corrosion from the inside will continue at those places unabated, as it will at all gaps, fittings and tees where the terminal end of a liner exists. Likewise, the pipe will continue to corrode from the outside.

Maintenance Considerations
Once a pipe has been lined with a CIPP resin, traditional drain cleaning machines with rotating cables and cutter heads (often used for cleaning and unclogging blocked pipes), may cause damage to the CIPP lining. The alternative, high-pressure water jetting, is often the recommended method of cleaning a CIPP liner but can be considerably more expensive, disruptive and messy.

Durability and Warranty Concerns
Manufacturers’ Warranties
CIPP warranties are only as good as the company that installs them. Potential buyers should read the fine print carefully. Some manufacturers offer 12 months, while others provide limited warranties on the lining material for as long as 50 years, but the manufacturer warranty will not cover improper installation, which will likely be the cause for any claim that is made.

Installers’ Warranties
Similar to epoxy, it is important to understand how long the installer is offering to warrant workmanship and the material in the event it is determined that either the installation or material is defective. Likewise, it’s important to understand if repairs covered under warranty; will be completed by a technician who is certified on the lining product that was installed. Finding a certified technician to perform a repair under warranty on a particular lining product could be a challenge in some local markets as many local service plumbers and maintenance personnel may not be trained on working with lined pipes. As with epoxy, always confirm the warranties of both the manufacturer and the installer as well as the financial strength of the installer before making a purchase decision.

Additional Vendor Considerations
Has a third party, such as a construction manager, been hired to create a Request For Proposal (“RFP”), including full specifications for the project? Typical RFPs in the CIPP industry require extensive experience.
with the specific application intended for each project. To meet such a requirement, any vendor proposing to completely line the interior, above ground DWV system usually must show that they have successfully done such a project in the past and that such project met all industry standards and is without ongoing problems. It is doubtful that any contractor has completed a “complete” relining of every DWV pipe in a building such that they could reasonably claim that lining only is an equivalent substitute for the installation of a completely new piping system.

As with epoxy lining solutions on a domestic water system, CIPP installers may not be able to obtain or provide payment and performance bonds. The key question to ask in this regard is: “Even though a performance bond may not be a bid requirement, does the building owner(s) feel comfortable hiring a contractor that does not have the ability to bond (e.g., obtain a third-party guaranty) their work?”

**Cost Considerations**

**Financing**
Some financial institutions have declined to finance CIPP and epoxy solutions. This can be challenging for properties that do not have the capital improvement budgets or, in the case of condominiums, have not established sufficient reserves in advance. As a result, the project could require a significant outlay of cash or a special assessment.

**Lining vs. Pipe Replacement**
There are certain circumstances when CIPP solutions are appropriate. Many large underground waste and sewer lines are expensive to excavate and replace, and CIPP solutions can be very beneficial in these circumstances. Likewise, for larger drain and sewer pipes buried under concrete slabs, access can also be very expensive, making CIPP a more cost-effective solution than replacement. However, within the building envelope, the risks and quality concerns associated with CIPP, compared with the cost competitiveness of a repipe, raise serious doubts as to whether CIPP should be used inside the property.

**CIPP Lining Conclusions**
While there are certain underground applications for CIPP lining that clearly make sense, the amount of risk associated with CIPP lining within the building envelope has led the authors to conclude that CIPP is not a comparable alternative to pipe replacement of drain, waste and vent piping within the interior of a building. Before making an investment decision, it is always advisable for a property to explore all its options, including a repipe, to ensure their community is making the most informed decision possible about fixing its failing pipes.
Final Conclusions

For a variety of reasons ranging from health issues, to installation challenges, to warranty concerns, to financial implications and cost comparisons to pipe replacement, the authors do not believe pipe lining solutions are a viable resolution to pipe problems within the building envelope. Both epoxy lining and CIPP lining pose considerable risks when used indoors and cannot be recommended as an alternative to a complete system repipe. SageWater has encountered failed pipe lining jobs, as well as partially completed pipe lining jobs, that now require a full pipe replacement, after the building has incurred the cost of the lining process. Failed pipe lining has resulted in numerous lawsuits across the lining industry. If a community is considering lining their pipes, the authors highly recommend obtaining a repipe bid at the same time, to effectively compare the costs, benefits and risks of each option.

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  Andrew J. Whelton: Assistant Professor of Environmental Engineering, Perdue University
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- For additional visual evidence, we suggest readers watch “Failures Of Epoxy Liner in Domestic Potable Water Systems” online at
  http://www.youtube.com/watch?v=ZX98R3L3zA